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JP62229891

Public Patent Information (A)

Title of the Invention Multiple Wavelength Semi-Conductor Light Source

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Specifications

1. Title of the Invention Multiple Wavelength Semi-Conductor Light Source

2. Scope of the Patent Request

(1) A multiple wavelength semiconductor light source with the characteristics that: With a semiconductor laser array on which a non-reflective coat has been applied to one side of the light-emitting edge, a light output fiber on which a high-reflectivity plane has been constructed in the vicinity of the diffraction grating and the edge, possessing an optical combined circuit that synthesizes the diffraction grating spaces semi-conductor laser array, diffraction grating interval as well as a light output fiber, and within the semi-conductor laser array of the i-th order, the light resulting from the light-emitting edge on which the non-reflective coat of the semi-conductor laser has been applied is incident to the diffraction grating, and that diffracted light converges on the high-reflectivity plane of the light output fiber end vicinity, part of that optic electricity is reflected in the opposite direction and once again is incident to the diffraction grating, and at the same time that the diffracted light converges on the light-emitting end where the non-reflective coat of the i-th order semi-conductor laser has been applied, part of the diffracted light that has converged onto the high-reflectivity plane permeates and is combined with the light output fiber.

(2) The afore-mentioned multiple wavelength semiconductor light source in the requested scope of Section 1, with the characteristics being that the optic combined circuit is a collimating lens, and the diffraction grating is a planar diffraction grating.

(3) The afore-mentioned multiple wavelength semiconductor light source in the requested scope of Section 1, with the characteristics being that the light-combined circuit is, at the same time the light combined circuit is combined with each outputted light relative to each light-emitting edge where the non-reflective coat of the semiconductor laser has been applied, the 3-D waveguide path array that is changed to a fixed waveguide path interval from the semiconductor laser array waveguide path interval, as well as the slab waveguide path that follows this, and the diffraction grating is the curved diffraction grating constructed on the edge of the slab waveguide path, the light output fiber is created on the slab waveguide path edge located on the Roland circle of the curved diffraction grating along with the edge where the 3-D waveguide path array pitch has been changed.

3. Detailed Explanation about the Invention (Field of the Invention)

This invention concerns the multiple wavelength semiconductor light source, and more specifically, deals with multiple wavelength semiconductor light sources that excel at temperature stability with a small shape.

The Present Technology

Multiple wavelength light sources are an indispensable part of the wavelength multiple transmission system. As far as the present wavelength multiple transmission systems, they are created using multiple semiconductor lasers that possess differing radiated light wavelengths and optic elements to align wavelength, but in this construction, it is difficult to control with high precision the radiated light wavelengths of the individual semiconductor lasers in the manufacturing step, so it has been impossible to achieve wavelength intervals less than 20 nm without sacrificing high yield. Also, since they use individual semiconductor laser chips, there has been the problem that the fabrication processes increase in proportion to wavelength multiplication. In order to resolve this issue, people have constructed multiple activated waveguide paths within the same semiconductor substrate, and by constructing diffraction gratings with different periodicities on each waveguide path, monolithic accumulative-model DFB laser experiments were attempted that achieved multiple adjacent radiated light wavelengths.

For instance, Okuda, et al, in JJAP Vol 23, pp L904-L906 (1984), showed the results of their experiment with the 5 wave accumulative GaInAsP DFB laser, where they continuously oscillated 5 elements simultaneously in an area of wavelength 1.3 micrometers and where they confirmed the laser oscillation of the 5 wavelengths at approximately 5 nm wavelength intervals. However, the radiated light wavelength temperature coefficient was reported to be approximately 0.1 nm/dey, this is, in comparison to the approximately 0.5 nm/dey radiated light wavelength temperature coefficient of the current Fabry-Perot model GaInAsP semiconductor laser, a reduction to 1/5 the value, and in the temperature scope of 50° C, fluctuations of the 5 nm radiated light wavelength appear, so when the radiated light wavelength interval is 5 nm, the signal will be coupled in an adjacent channel on the receptor side. Furthermore, when using an accumulative-model DFB laser, it is possible to shrink the wavelength interval, but the control technology concerning that absolute value is still not complete, and it is difficult to obtain absolute wavelength precision less than 5 nm. As a method to resolve this difficulty, it is thought that a semiconductor laser that uses a highly stable outer resonator could be used. Many people have attempted experiments to obtain laser oscillation by applying an AR coat on the light-emitting edge of one side of the semiconductor and restraining Fabry-Perot-mode oscillation, and then combining to this an outer resonator that possesses wavelength selectivity. For instance, J.A. Rossi et al reported in Appl. Phys. Lott. Vol. 23, No. 1, 1 July 1973 pp. 25-27, experiments using a wavelength variable semiconductor laser, in the vicinity of a radiated light central wavelength of 0.89 nm in the area of approximately 10 nm, by lens-combining a diffraction grating that possesses 1208 pieces/nm gutters and a $Al_xGa_{1-x}As/GaAs$ SH laser where an AR coat has been applied on one side. Concerning this report, since the diffracted light is directly returned to the semiconductor laser from the diffraction grating, if multiple wavelength light sources are constructed using this method, coupling will appear between different semiconductor lasers and independent oscillation becomes impossible. Figure 3 is an example of a multiple wavelength semiconductor light source analogous to current technology, where 1 is the semiconductor laser array, 2 is the light-emitting edge with the AR coat, 3 is the light-emitting edge without the AR coat, 4 is the

collimating lens, 5 is the diffraction grating, 6 is the output fiber and 7 is the output fiber edge.

As in Figure 3, the light emitted from the light-emitting edge 2-i, on which the i-th order semiconductor laser non-reflective coat within the semiconductor laser array 1 has been applied is converted to a parallel luminous flux by the collimating lens 4, and is incident at an angle of θ_i to the normal of the diffraction grating 5, and similarly if it is diffracted at an angle θ_i then it will return to the light-emitting edge 2-i, and laser oscillation at a wavelength λ_i will be possible. At this time the conditions of the first equation must be met.

Equation (1)

Here a is the grating constant of the diffraction grating and the diffraction degree is assumed to be 1. Similarly, the light emitted from the light-emitting edge 2-j on which the j-th order AR coat has been applied is incident to the normal of the diffraction grating 5 at an angle of θ_j. and if it is diffracted at the same angle θ_j, then it will be returned to the light-emitting edge 2-j, and that laser oscillation wavelength λ_j will be determined by the second equation.

Equation (2)

Incidentally, when the light emitted from the light-emitting edge 2-i is incident to the diffraction grating at an angle θ_i, when it is diffracted at an angle θ_j, the wavelength will be determined by equation 3.

Equation (3)

This diffracted light is reflected by the light-emitting edge 3-j on which the semiconductor laser 1-j AR has not been applied, and since it will be emitted from the light-emitting edge 2-j on which no AR has been applied, it will be incident to the diffraction grating, and the light of the wavelength that fulfills Equation 3 will be re-diffracted at θ_i and will return to the semiconductor laser 1-i. In other words, the 2 individual lasers 1-i and 1-j will be combined, and it will be possible to oscillate the wavelength $(\lambda_i + \lambda_j)/2$. Similarly, there is the possibility of generating laser oscillation that is combined for all of the individual lasers within the semiconductor laser array 1, and we cannot expect each laser to oscillate stably and independently.

Goal of the Invention

This invention solves the afore-mentioned problems, and offers a highly stable multiple wavelength semiconductor light source.

Structure of the Invention

This invention has as its most important characteristic that it can obtain laser oscillation at multiple wavelengths by combining an outer resonator on which a semiconductor laser, where on one side of the light-emitting edge an AR (non-reflective) coat has been applied, has been combined with a diffraction grating and a reflector. Whereas up until now, the diffracted light was returned directly to the semiconductor laser from the diffraction grating, with this invention, the reflected light will be received by a reflector that reflects it in the opposite direction, and the diffracted light will be reflected by this reflector to again be incident to the diffraction grating at an angle equal to that of the diffraction, and when the diffracted light is again returned to the semiconductor laser, and the adjacent semiconductor spacing goes through the diffraction grating without mutually combining, it is possible to independently obtain stable oscillation.

Explanation of Experiment Examples

Figure 1 is an example of the first experiment with this invention. 8 is the semiconductor laser array, 9 is the light-emitting end on which the AR (non-reflective) coat has been applied, 10 is the light-emitting end on which the AR (non-reflective coat has not been applied, 11 is the collimating lens, 12 is the diffraction grating, and 13 is the output fiber made with a high reflectivity film on its edge.

The semiconductor laser array 8 deposits a two-layer SiO2 film on the end of a $Ga_xIn_{1-x}As_yP_{1-y}$/InP BH model 2-element laser array that has a radiated light wavelength of 1.3 micrometers, and used a reflectivity of approximately 10^{-4}. The array pitch is 300 micrometers. The collimating lens 11 is f=72 mm, and in order for the reflectivity to be below 1% in the vicinity of 1.3 micrometers, we applied an AR (non-reflective) coat to both sides. The diffraction grating 12 uses a grating spacing of a=2.5 micrometers, a blaze wavelength of 1.3 micrometers and a blaze angle of 15. The output fiber 13 uses a spot-size of 5 micrometers, and a single mode fiber with outer diameter 125 micrometers

where due to multiple layers of SiO_2 and TiO_2 on the edge, a highly reflective layer has been created with reflectivity of 0.9.

The following is an explanation of a summary of the operations of the experiment in Figure 1.

The light emitted from the edge 9-1 on which the semiconductor laser 8-1 AR (non-reflective) coat has been applied is converted by the collimating lens 11 to a parallel luminous flux, and is incident to the normal of the diffraction grating 12 at an angle of θ_1. The light of wavelength λ_1 passes through the collimating lens 11 at an angle θ_1' and forms an image on the end of the output fiber 13. 90% of the light at the edge of the output fiber is reflected, and after being converted to a parallel luminous flux by the collimating lens 11, it is again reflected to the diffraction grating 12 at an angle θ_1', and being diffracted in the direction of the emitted angle θ_1, it passes through the collimating lens to become an image on the end 9-1 on which the semiconductor laser 8-1 AR (non-reflective) coat has been applied. The light imaged on the edge 9-1 propagates through the activated waveguide path, and amplified, it is reflected on the end 10-1 on which the AR (non-reflective) coat has not been applied to arrive at the end 9-1. As explained above, the outer resonator of the wavelength selectivity, created due to the diffraction grating and the reflector on the end of the output fiber, and the semiconductor laser amplifier where the AR (non-reflective) coat has been applied one side are combined to obtain laser oscillation of wavelength λ_1. Similarly, the light emitted from the end 9-2 where the semiconductor laser 8-2 AR (non-reflective) coat has been applied is incident to the diffraction grating at an angle of θ_2, and diffracted at an emitted angle of θ_1', it is reflected to the end of the output fiber 13, and returning to the semiconductor laser 8-2, oscillation of the wavelength λ_2 is obtained. At this time, the conditions to obtain laser oscillation of wavelengths λ_1 and λ_2, as well as the conditions for oscillation of the semiconductor laser 8-1 and 8-2 at wavelength λ_3 through the diffraction grating are calculated using the diffraction degree as primary in the following three equations.

Equation (1)

Equation (2)

Equation (3)

Here, the benefits of the semiconductor laser 8 can be obtained.

When the minimum and maximum are set at λ_{min} and λ_{max},

Equation (4)

By selecting the conditions, it is possible to prevent the oscillation of the mode in (3). Here, θ_{max} and θ_{min} can be calculated from the following:

Equation (5)

Equation (6)

In this experiment, we set λ_{min} = 1290 nm, λ_{max} = 1310 nm, and $\theta_1 = 14°$, $\theta_2 = 14.236°$, $\theta_1' = 16.026°$. Here, the following relationship is developed for the semiconductor laser array pitch P and the collimating lens focus distance f as well as θ_1, and θ_2.

Equation (7)

From the above relationship, as laser oscillation of λ_1 = 1,295 micrometers, λ_2 = 1,305 micrometers is obtained, we were able to obtain an aligned output light of both wavelengths from the output fiber.

Figure 2 is the example of the second experiment of this invention. 14 is the semiconductor laser array, 15 is the light-emitting edge on which the AR (non-reflective) coat has been applied, 16 is the light-emitting edge on which the AR (non-reflective) coat has not been applied, 17 is the light waveguide path array pitch converter, 18 is the slab waveguide path, 19 is the curved surface diffraction grating on the edge of the slab waveguide path, 20 is the output fiber constructed on the edge of the high-reflectivity film and 21 is the waveguide path substrate.

The operation is the same as for the first experiment. Since the current semiconductor laser array pitch generally requires greater than approximately 300 micrometers from the restrictions on the radiation device, in this experiment we created an array pitch converter, and reducing the wavelength interval, we attempted the miniaturization of the angle dispersion model outer resonator. In this experiment, we converted a 300 micrometer semiconductor laser array pitch to a 20 micrometer array pitch. The light-emitting edge of the array pitch converter 17 as well as the edge of the output fiber 20 are placed on the Roland circle of the curved surface diffraction grating 19, and by setting the grating interval of the curved surface grating to a=1.25 micrometers, n° = 2.3 and the curved radius (Roland circle radius) to R=11.2 mm, we were able to obtain laser oscillation of 1292.5 nm, 1297.5 nm, 1302.5 nm, and 1307.5 nm.

As explained above, in the two experiments, after applying the AR coat on the light-emitting edge combined with the outer resonator of the semiconductor laser array, and though we did not apply the AR coat to the other edge, it is obvious that if we did apply the coat on the high-reflectivity film, it would be effective in the reduction of the oscillation current.

Efficacy of the Invention

As explained above, with this invention, we obtained multiple wavelength laser oscillation by combining a semiconductor laser array where an AR coat has been applied, and an outer resonator of the wavelength selectivity that uses a diffraction grating and a reflector. However, by calibrating the angle and position of each part of the structure in order to fulfill the requirements of Equations (4) through (6), it is possible to obtain stable oscillation without creating coupling between each laser within the semiconductor laser array.

4. Simple Explanations of the Figures

Figure 1 shows an explanation of the first experiment with this invention.

Figure 2 shows an explanation of the second experiment with this invention.

Figure 3 shows the multiple wavelength semiconductor light source in current technology.

In the figures:

1, 8, 14 are the semiconductor laser array

2, 9, 15 are the light-emitting edge where the AR (non-reflective) coat has been applied

4, 11 are the collimating lens

5, 12 are the diffraction grating

6 is the output fiber

7 is the edge of the output fiber

10, 16 are the light-emitting edge where the AR (non-reflective) coat has not been applied

13 is the output fiber that has the high-reflectivity film on its edge

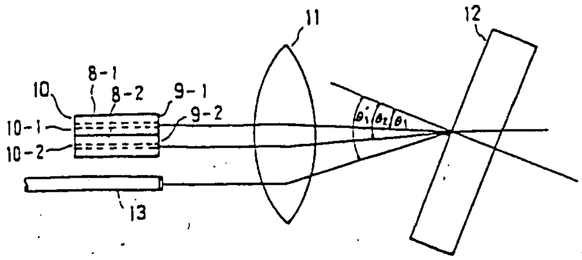
17 is the array pitch converter of the optic waveguide path

18 is the slab waveguide path

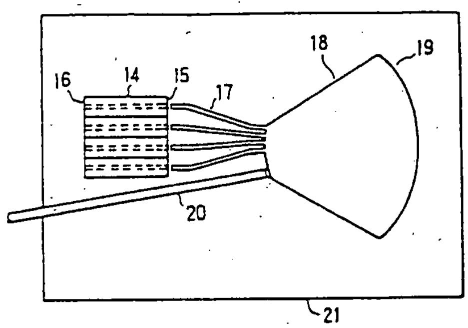
19 is the curved surface diffraction grating created on the edge of the slab waveguide path

20 is the output fiber that has the high-reflectivity film on its edge

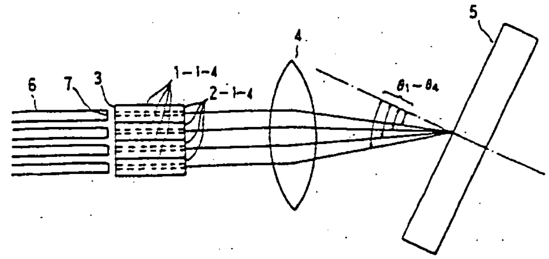
21 is the waveguide path substrate



第 1 図



第 2 図



第 3 図

MULTIPLE-WAVELENGTH SEMICONDUCTOR LIGHT SOURCE

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Inventor(s): NISHI NORIO
Applicant(s):: NIPPON TELEGR & TELEPH CORP
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Abstract

PURPOSE:To obtain a highly stable multiple-wavelength semicouductor light source, by coupling a semiconductor laser array, in which a reflectionless coating is applied on a light emitting end surface on one side to an outer resonator, in which a diffraction grating is combined with a reflector, and obtaining laser oscillations in multiple wavelengths.

CONSTITUTION:Light is emitted from an end surface 9-1 of a semiconductor laser unit 8-l, on which an AR (reflectionless) coating is applied. The light is inputted to a diffraction grating 12 at an angle theta1 with respect to the normal line to the grating 12 through a collimating lens ll. Light having a wavelength #11 passes the lens ll at a diffraction angle theta'1, and an image is formed at the end surface of an output fiber 13. At the end surface of the fiber 13, where a high reflectivity layer is provided, 90% of the light is reflected and inputted again to the diffraction grating 12. The light is diffracted in the direction of the output angle theta1, propagated in an active lightguide, and amplified. The light is reflected by an end surface 10-l and reaches the end surface 9-l. Thus laser oscillation at the wavelength #11 is obtained. By the same way, light, which is emitted from an and surface 9-2 of a semiconductor laser unit 2, on which the AR coating is provided' is inputted to the diffraction grating 12 at an angle theta2. The light is diffracted at an output angle theta'1, and laser oscillation at a wavelength #12 is obtained.

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⑤発明の名称　多波長半導体光源

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明　細　書

1.発明の名称　多波長半導体光源

2.特許請求の範囲

(1) 片側の光出射端面に無反射コートを施した半導体レーザアレイと，回折格子と端面近傍に高反射率平面を設けた光出力ファイバと半導体レーザアレイ・回折格子間および光出力ファイバ・回折格子間を総合する光結合回路を有し，半導体レーザアレイ中の第 i 番目の半導体レーザの無反射コートを施した光出射端面から出射した光は回折格子に入射し，その回折光は光出力ファイバ端面近傍の高反射率平面上に収束し，その光電力の一部は逆方向に反射して再び回折格子に入射し，その回折光が第 i 番目の半導体レーザの無反射コートを施した光出射端面に収束するとともに，高反射率平面上に収束した回折光の一部は透過して光出力ファイバに結合することを特徴とする多波長半導体光源。

(2) 光結合回路はコリメートレンズであり、回折格子は平面回折格子であることを特徴とする第1項の請求範囲に記載の多波長半導体光源。

(3) 光結合回路は半導体レーザアレイの無反射コートを施した各光出射端面と相対して各出射光に結合するとともに半導体レーザアレイの導波路間隔から所定の導波路間隔に変換する3次元導波路アレイおよびこれに続くスラブ導波路であり，回折格子はスラブ導波路の端部に設けた曲面回折格子であり，光出力ファイバは3次元導波路アレイのピッチ変換された端面とともに曲面回折格子のローランド円上にあるスラブ導波路端面に設けられていることを特徴とする第1項の請求範囲に記載の多波長半導体光源。

3.発明の詳細な説明
発明の分野
本発明は多波長半導体光源に関するものであり具体的には，小形にして温度安定性に優れた多波長半導体光源に関するものである。

従来の技術

多波長光源は波長多重伝送システムに不可欠な部品である。従来の波長多重伝送システムにおいては異なる発光波長を有する複数の半導体レーザと，光合波器を用いて構成しているが，この構造では個々の半導体レーザの発光波長を製造段階で高精度に制御することが困難なため，高歩留を損うことなく波長間隔を20 nm 以下とすることが不可能であつた。また個別の半導体レーザチップを使用するため組立工程が波長多重数に比例して増大する欠点があつた。この欠点を解決するために同一半導体基板内に複数の活性導波路を設け，かつ各導波路に周期の異なる回折格子を設けることにより近接した複数の発光波長を得るモノリシック集積形 *DFB* レーザの実験が試みられている。例えば奥田らは *J.J.A.P Vol.23, pp.L904〜L906(1984)* で波長1.3 μm付近で5素子同時に連続発振する5波集積 *GaInAsP DFB* レーザの実験結果について述べており，約5 nmの波長間隔で5波長のレーザ発振が確認されている。しかし発光波長の温度係数は約0.1 nm/deg と報告されており，これは従来のファブリペロー形 *GaInAsP* 半導体レーザの発光波長の温度係数約0.5 nm/deg に比べて⅕に低減しているものの，50℃の温度範囲では5 nmの発光波長の変動を生じることとなり，5 nmの発光波長間隔の場合には受光分波側で信号が隣接チャネルに結合されることとなる。さらに集積形 *DFB* レーザの場合に波長間隔を縮めることは可能であるが，その絶対値については未だ制御技術が十分ではなく，5 nm以下の絶対波長精度を得るのは困難である。この欠点を解決する方法として，高安定な外部共振器を用いた半導体レーザが考えられる。半導体レーザの片側の光出射端面に *AR* コートを施してファブリペローモード発振を抑圧し，これに波長選択性を有する外部共振器を結合してレーザ発振を得る方法は従来多く試みられており，例えば *J.A.Rossi* 等は *Appl.Phys.Lett.Vol.23, No.1, 1 July 1973 pp.25-27* の中で片端 *AR* コートした $Al_xGa_{1-x}As/GaAs$ *SH* レーザと1208本/mm 溝を有する回折格子をレンズ結合して0.89 μmの発光中心波長の近傍で約10 nm の範囲で波長可変な半導体レーザについて報告している。この報告においては回折格子からの回折光を直接半導体レーザに帰還しているため，この方法で多波長光源を構成すると異なつた半導体レーザ間に結合が生じて独立な発振が不可能となる。第3図は従来技術から類推した多波長半導体光源の例であり，1は半導体レーザアレイ，2は *AR* コートを施した光出射端面，3は *AR* コートを施さない光出射端面，4はコリメートレンズ，5は回折格子，6は出力ファイバ，7は出力ファイバ端面である。

第3図において，半導体レーザアレイ1の中の第 i 番目の半導体レーザの無反射コートを施した光出射端面 $2\text{-}i$ から出射した光はコリメートレンズ4により平行光束となり，回折格子5の法線に対して θi の角度で入射し，同じく θi の角度に回折すれば光出射端面 $2\text{-}i$ に帰還されることとなり波長 λi のレーザ発振が可能となる。この時第1式の関係が満足されなければならない。

$$2a\sin\theta i = \lambda i \qquad (1)$$

ここで a は回折格子の格子定数であり，回折次数は1と仮定している。同様に第 j 番目の *AR* コートを施した光出射端面 $2\text{-}j$ から出射した光が回折格子5の法線に対して θj の角度で入射し，同じく θj の角度に回折すれば，光出射端面 $2\text{-}j$ に帰還されることになり，そのレーザ発振波長 λj は第2式で与えられる。

$$2a\sin\theta j = \lambda j \qquad (2)$$

ところで，光出射端面 $2\text{-}i$ から出射した光が角度 θi で回折格子に入射し，角度 θj で回折する場合には波長が(3)式で与えられる。

$$a(\sin\theta i + \sin\theta j) = (\lambda i + \lambda j)/2 \qquad (3)$$

この回折光は半導体レーザ $1\text{-}j$ の *AR* を施さない光出射端面 $3\text{-}j$ で反射され，*AR* を施さない光出射端面 $2\text{-}j$ から出射されて角度 θj で回折格子に入射するため，第3式を満足する波長の光は θi で再度回折されて半導体レーザ $1\text{-}i$ に帰還されることとなる。すなわち2個のレーザ $1\text{-}i$, $1\text{-}j$ が結合されて $(\lambda i+\lambda j)/2$ の波長で発振する可能性が生ずる。同様に半導体レーザアレイ1の中のすべての1対

のレーザに対して結合したレーザ発振を起す可能性があり，各レーザが独立に，安定な発振をすることは望めない。

発明の目的

本発明は上記の欠点を解決した，高安定な多波長半導体光源を提供することにある。

発明の構成

本発明は片側の光出射端面AR（無反射）コートを施した半導体レーザアレーと回折格子と反射器を組み合わせた外部共振器を結合させて多波長のレーザ発振を得ることを最も主要な特徴とする。従来では回折格子からの回折光を直接半導体レーザに帰還していたのに対し，本発明では回折光を逆方向に反射する反射器を設け，回折光がこの反射器で反射されて回折角に等しい角度で回折格子に再度入射し，再度回折した光を半導体レーザに帰還することにより，隣接した半導体レーザ間が回折格子を介して相互に結合することなく，独立に安定な発振を得るようにしている。

実施例の説明

第1図は本発明の第1の実施例であり，8は半導体レーザアレイ，9はAR（無反射）コートを施した光出射端面，10はAR（無反射）コートを施さない光出射端面，11はコリメートレンズ，12は回折格子，13は端面に高反射率膜を形成した出力ファイバである。

半導体レーザアレイ8は1.3 μmの発光波長を有する$Ga_xIn_{1-x}As_yP_{1-y}/InP$ BH形2素子レーザアレイの端面9にSiO_2の2層膜を蒸着し，反射率を約10^{-4}として用いた。アレイのピッチは300 μmである。コリメートレンズ11は$f=72$ mmであり，1.3 μmの近傍で反射率が1%以下となるよう両面にAR（無反射）コートを施してある。回折格子12は格子定数$a=2.5$ μm，ブレーズ波長1.3 μm，ブレーズ角15°のものを用いた。出力ファイバ13はスポットサイズ5 μm，外径125 μm の単一モードファイバ端面にSiO_2，TiO_2の多層膜による反射率0.9の高反射率層を設けたものを用いた。

第1図の実施例における動作の概要を以下に説明する。

半導体レーザ8-1のAR（無反射）コートを施した端面9-1から出射した光はコリメートレンズ11により平行光束に変換され，回折格子12の法線に対し角度θ_1で入射する。波長λ_1の光は回折角θ_1'でコリメートレンズ11を通り出力ファイバ13の端面に結像する。出力ファイバ13の端面で90%の光は反射され，コリメートレンズ11で平行光束に変換された後角度θ_1'で回折格子12に再度入射し，出射角θ_1の方向に回折してコリメートレンズ11を通り半導体レーザ8-1のAR（無反射）コートを施した端面9-1に結像する。端面9-1で結像した光は活性導波路中を伝搬，増幅されてAR（無反射）コートを施さない端面10-1で反射され端面9-1に至る。以上のように回折格子と出力ファイバ端面の反射器により構成された波長選択性の外部共振器と片端面にAR（無反射）コートを施した半導体レーザ増幅器を結合させて波長λ_1のレーザ発振を得る。同様に半導体レーザ8-2のAR（無反射）コートを施した端面9-2から出射した光を回折格子12にθ_2なる角度で入射し，θ_1'出射角に回折させて出力ファイバ13の端面で反射させて半導体レーザ8-2に帰還することにより波長λ_2のレーザ発振を得る。このとき波長λ_1，λ_2のレーザ発振を得る条件および，半導体レーザ8-1,8-2が回折格子を介して波長λ_3で発振する条件は回折の次数を1次として第1式～第3式で与えられる。

$$a(\sin\theta_1+\sin\theta_1')=\lambda_1 \quad (1)$$

$$a(\sin\theta_2+\sin\theta_1')=\lambda_2 \quad (2)$$

$$a(\sin\theta_1+\sin\theta_2)=\lambda_3 \quad (3)$$

ここで半導体レーザ8の利得が得られる。
波長の最小値，最大値をλmin，λmaxとしたとき

$$\theta_1,\theta_2>\theta_{max} \text{ 又は } \theta_1,\theta_2<\theta_{min} \quad (4)$$

なる条件を選べば(3)のモードの発振は阻止することができる。

ここで，θmax，θminは次式で与えられる

$$\theta max=\sin^{-1}(\lambda max/2a) \quad (5)$$

$$\theta min=\sin^{-1}(\lambda min/2a) \quad (6)$$

本実施例では $\lambda_{min}=1290nm$, $\lambda_{max}=1310nm$ として $\theta_1=14°$, $\theta_2=14.236°$, $\theta_1'=16.026°$ とした。ここで半導体レーザアレイピッチ P とコリメートレンズの焦点距離 f および θ_1, θ_2 の間には次の関係が成り立つ。

$$f\cdot\tan(\theta_1-\theta_2)\doteqdot P \qquad (7)$$

以上の構成により $\lambda_1=1.295\mu m$, $\lambda_2=1.305\mu m$ のレーザ発振を得るとともに、両波長の合波出力光を出力ファイバから得ることができた。

第2図は本発明の第2の実施例であり、14は半導体レーザアレイ、15はAR(無反射コートを施した光出射端面、16はAR(無反射)コートを施さない光出射端面、17は光導波路のアレイピッチ変換部、18はスラブ導波路、19はスラブ導波路の端部に設けた曲面回折格子、20は端面に高反射率膜を設けた出力ファイバ、21は導波路基板である。

動作は第1の実施例と同等である。従来の半導体レーザアレイのピッチは主に放熱設計上の制約から約300μm以上を必要としているため、本実施例ではアレイピッチ変換部を設けて、波長間隔の縮少、角度分散形外部共振器の小形化をはかっている。本実施例においては300μmの半導体レーザアレイピッチを20μmのアレイピッチに変換した。アレイピッチ変換部17の光出射端面および、出力ファイバ20の端面は曲面回折格子19のローランド円上に配置し、曲面回折格子の格子定数 $a=1.25\mu m$, $n_0=2.3$ 曲率半径(ローランド円直径)を $R=11.2mm$ とすることにより1292.5nm, 1297.5nm, 1302.5nm, 1307.5nm のレーザ発振を得ることができた。

以上に説明した第1および第2の実施例においては半導体レーザアレイの外部共振器と結合する光出射端面にARコートを施し、他の端面にはARコートを施さないとしたが、さらに高反射率膜をコートを施せば発振閾値電流の低減に有効であることは自明である。

発明の効果

以上に説明したように、本発明においては、回折格子と反射器を組み合わせた波長選択性の外部共振器とARコートを施した半導体レーザアレイを結合して多波長レーザ発振を得るが、そのとき第(4)〜第(6)式を満足するように各構成部品の位置および角度を設定すれば、半導体レーザアレイ内の各レーザ間の結合を生ずることなく安定な発振を得ることが可能となる。

4. 図面の簡単な説明

第1図は、本発明の第1実施例の説明図を示す。
第2図は、本発明の第2実施例の説明図を示す。
第3図は、従来の技術による多波長半導体光源を示す。

図において、

1,8,14 は、半導体レーザアレイ
2,9,15 は、AR(無反射)コートを施した光出射端面
4,11 は、コリメートレンズ
5,12 は、回折格子
6 は、出力ファイバ
7 は、出力ファイバ端面
10,16 は、AR(無反射)コートを施さない出射端面
13 は、端面に高反射率膜を形成した出力ファイバ
17 は、光導波路のアレイピッチ変換部
18 は、スラブ導波路
19 は、スラブ導波路の端部に設けた曲面回折格子
20 は、端面に高反射率膜を設けた出力ファイバ
21 は、導波路基板

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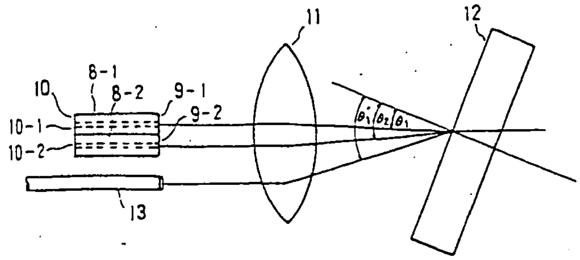
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12
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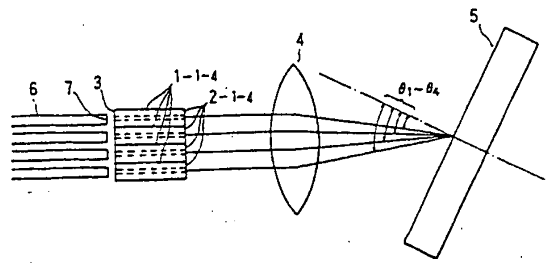
8-1
8-2
9-1
9-2
10-1
10-2
13
θ1
θ2

第 1 図


5
4
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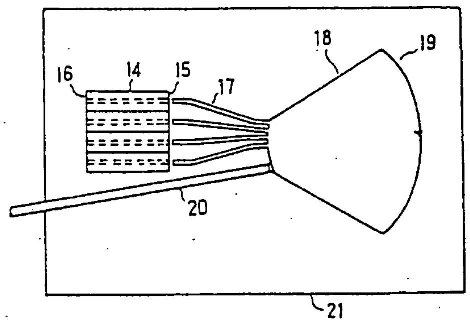
3
1-1-4
2-1-4
θ1-θ4

第 3 図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第 2 図

Attn: Mr. Jason Farmer

19 Department of Japan Patent.
11 Patent Application Disclosure
12 Disclosed Patent Official Report
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21 Patent Application?? Sho61-71866
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